USER DATA FORMATTING FOR SEARCH AND RETRIEVAL ON 19MM DATA RECORDERS

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ABSTRACT

Search and retrieval efficiencies are intimately related to the method of user data formatting used on 19 millimeter (mm) rotary digital data recorders. The formatting must be designed for the feature set of the recorder in order to make optimum use of the recorder capabilities.

INTRODUCTION

In data recording applications it is often necessary to be able to find desired sections or pieces of data without performing a sequential read of the entire tape. Due to the high areal density of recording inherent in 19mm data recorders, the implementation of an efficient search philosophy becomes crucial. The physical format features, as well as the user format, contribute to the efficiency of any search or retrieval process.

LONGITUDINAL SEARCH

A brief review of longitudinal timecode search provides a frame of reference for the helical search discussions.

Here, timecode is placed on one of the many parallel tracks of the longitudinal recorder. A search is performed by running the recorder at a desired reproduce speed while reading the timecode track. When the desired time is approached, the recorder may slow down to operate at a desired data reproduce speed. If, for example, an IRIG-B timecode is used, then it is fairly easy to determine time to less than a millisecond. The major limitation to this process will be the interlaced head placement tolerance, which is a maximum of 2 mils. At two inches per second (ips), the tape will require 1 millisecond to traverse this distance which will translate to a minimum uncertainty of 1 millisecond in the timecode to data correlation. The timecode data rate may approach the frequency on any of the other channels since the timecode track is identical to any other track unless a voice track is used.

19mm FORMAT

The current 19mm digital data recording formats, MIL-STD-2179A and ANSI ID-1, are identical in so far as search is concerned. The format provides for a high speed helical digital data channel plus two, analog or digital, longitudinal channels at a much lower rate as well as a third control track for servo use. The high speed data is recorded on the tape in the form of helical tracks.

The 19mm recorder will have a tape path similar to the example in figure 1. The distance from the read/write longitudinal head to the start of the helical track is specified in the standards as 118.7 ± 0.3 millimeters. The monitor head is only present if there are longitudinal read-after-write features. The requirement for the same gap to be used for record and reproduce is one constraint on the performance of the longitudinal channels.

The helical recording process involves the use of buffers for the error correction circuitry (ECC) as shown in figure 2. The user data is put into a buffer where a two dimensional Reed-Solomon ECC code is attached. Multiple ECC blocks are recorded in a single helical track to provide for enhanced burst error correction capability. Additionally, more than one helical track may be recorded simultaneously. A cylindrical drum assembly with 270 degrees of wrap and four equidistant record head assemblies will be recording 3 helical tracks simultaneously.

The helical data reproduce process is the mirror image of the record process with the exception of error detection and correction.

The longitudinal tracks are usually designated for timecode and annotation data. These tracks are recorded by a longitudinal head located in the tape path. The tracks are normally of medium band performance and are designed to contain relatively low quality data compared to the helical data capabilities. MIL-STD-2179A specifies a flux density of

5,555 bits per inch, digital Manchester data, for the longitudinal channels. There is no specified ECC for the longitudinal channels.

Contained within the formats is a capability to identify each helical track uniquely, with the track identifier (track ID). The track ID is recorded in the preamble of every track and a subset of the track ID is recorded within the longitudinal control track. The longitudinal control track is used by the servo system of the recorder to identify the location of track sets.

LATENCIES AND DELAYS

Latencies cause inherent delays in the system which are not immediately apparent to the user but are the result of the data being stored in buffers. Latencies are not necessarily consistent from machine to machine. For delays, a reference point must be used and this point will be the instant when a byte of data is present on the helical data input interface for recording. Examples of latencies and delays would be the time difference between a byte being recorded and the user receiving the byte back during a read-after-write. For search and reproduce, the important delay to consider is the difference between a byte being reproduced and the timecode reproduction.

Helical Record Latency

There are multiple delay causing latencies involved within the helical record process. The first delay is the amount of time required to fill at least one FCC buffer so that the two dimensional ECC code may be appended. An entire ECC buffer must be stored since the data is loaded into the buffer in the vertical dimension and it is recorded on to the tape in the horizontal direction. In many architectures, if not all, more than one track of buffering is present between the input data and the record heads. If the user data must be aligned to helical track boundaries, as in video, then even more buffers are required to synchronize the user data with the revolution of the scanner, each of which has a latency. If there is a buffer on the front end of the recorder, then its latency would also have to be considered.

Helical Reproduce Latency

The helical reproduce latency is generated during the process of correcting the data. Since the correction process is more complex than the generation process, more buffering of the data may be required, and as such the reproduce latency may be more than the record latency.

Tape Transit Delay

The current specifications allow for a ±0.3 millimeter tolerance on longitudinal head placement. The delay becomes the time required to move the tape up to 0.6 mm. This delay is similar to odd / even stack location offsets on longitudinal recorders. For ANSI ID-1, and MIL-STD-2179 recorders, the longitudinal tape speed is approximately 16 inches per second at a user input rate of 240 million bits per second. The tape speed will vary proportionally with the user data rate. The tape transit latency will vary inverse proportionally to the used data rate.

Longitudinal Delay

There is minimal delay within the longitudinal path except for the tape transit delay.

Total Delay - Helical to Longitudinal Example

The total delay for a 240 million bits per second (Mbps) hypothetical recorder is as follows:

Number of tracks per second	= 830
Number of record buffers	= 5
Number of reproduce buffers	= 6
Tape transit offset	= 0.6 mm
Tape speed	= 397.2 mm/sec
	= 15.64 ips

Record Delay	= 6.02 ms
Reproduce Delay	= 7.22 ms
Tape transit Delay	= 1.51 ms
Total Delay	= 14.75 ms

The record delay is calculated by dividing the user data rate by the number of record buffers (5) and the number of bits per buffer (288864 bits). The reproduce delay is calculated by dividing the user data rate by the number of reproduce buffers (6) and the number of bits per buffer. The tape transit delay is calculated by multiplying the tape speed times the size of the head placement tolerance (0.3 mm).

The total time displacement between the helical data and the timecode data can be 15 milliseconds at 240 million bits per second (Mbps). At 24 Mbps, the displacement will be 150 milliseconds. This results in a total uncertainty of 3.6 million bits of user data relative to the associated timecode. This is similar to having a longitudinal interlaced head placement tolerance error of 6 millimeters (0.23 inches). This is acceptable for video recording, from which the 19mm formats were derived, due to the frame data occurring only 60 times per second. This may or may not be acceptable for instrumentation recording. Even an architecture with no ECC, would have to allow for the longitudinal head placement tolerance which would have the same effect as a longitudinal interlaced head placement tolerance of 0.6 millimeters.

Use of the Timecode Track

MIL-STD-2179A specifies that IRIG-B timecode be recorded on the timecode track, if timecode is recorded. ANSI ID-1 does not specify a particular timecode. Actually, any other timecode could be used if that particular timecode met the user’s needs. The specified timecode should have a bandwidth that is consistent with the capabilities of the channel, at both the record and reproduce speeds as well as search speed. The search speed is typically between 160 and 300 ips. The timecode to data correlation should allow for the latencies and delays as discussed previously. If the resolution is adequate, then no further formatting need be added.

Use of the Annotation Track

The annotation channel provides similar bandwidth performance as the timecode channel. This channel can be used to identify the tape as well as augment the search process. Data can be recorded at the beginning of the tape to uniquely identify the acquisition processes and events that generated the data. Down the length of the tape, event marks and other data unrelated to time may be recorded to provide for different search scenarios besides strictly time. This data is most useful if it is entirely self contained so that the tape contains all of the information needed to extract any needed information. The data can also be used to provide recorder pertinent data such as recorded data rate and input configurations.

Embedded Timecode Data

If a high correlation between helical data and timecode is required, then the timecode information should also be embedded in the helical data stream. Search would still be done using the longitudinal timecode, but actual time calculations would be derived from the embedded time information. For continuous data, an embedded timecode would provide a potential for time resolution close to the period of a byte of output data. For burst type data, a timecode tag should be attached to every burst, as a minimum, if there is not a constant arrival time of burst packets.

Track ID

The track ID information may be used to find data, especially if there are large anomalies in the time of recording. The track ID information is available in the helical tracks as well as on the control track. This allows for a high speed search to be performed on the control track data. When the appropriate region of tape is reached, the data in the helical track may be used for fine positioning. For MIL-STD-2179A and ANSI ID-1, the helical tracks contain 36,108 bytes of user data each. The track ID will identify every 36,108 byte block of user data uniquely.

Multiple Recorders

The track IDs also provide a basis for paralleling multiple transports without skew between the data streams. This may be accomplished as long as there is a consistent means of starting the recorders with identical track IDs and identical start points in the helical track. With the track IDs, recording sessions that last longer than one tape may also be seamlessly generated by overlapping the recording of two recorders by a nominal amount. The track IDs may then be used to seamlessly transfer the reproduction data stream from the data on one tape to the data on the second tape.

SEARCH PERFORMANCE LIMITATIONS

The high speed search, greater than 160 ips, is conducted on longitudinal data only. This search speed will allow a large cartridge, 100 gigabyte user capacity, to be searched from the beginning of tape to the end of tape in approximately 5 minutes. The acceleration time to reach playback speed as well as the acceleration time to stop from search speed must be taken into account in devising an optimum search technique. For searching on timecode, these times can be taken into account by offsetting the desired time by the effect of the sum of the transport acceleration times. The effect of a 3 second deceleration from 160 ips results in 240 inches of tape being traversed during the stop. If it takes 1 second to accelerate to a playback speed of 1 ips, then another 0.5 inches of tape are traversed. A five percent tolerance on acceleration tines yields a ±12 inches uncertainty in where the tape will really stop. This must be taken into account, therefore the tape must be stopped 12 inches early in order to avoid an overshoot.

For searching to uncorrelated data such as event marks, allowance must be made for the coarse correlation between event mark detection and helical data. The search algorithms cannot predict when the desired event mark will be detected. The event mark must either lead the desired data by the deceleration tape distances, i.e. 240 inches, or the system must be able to reverse direction and recover the event mark at normal playback speeds. If the desired playback speed is very low, say 1 ips, then it would take 4 minutes to perform a reverse read at this speed. For low speed applications, it nay be desireable to have the reverse speed be a tape speed somewhere between the search speed and the reverse speed in order to minimize the total search time. For example, the above case would lead to a maximum search time of 9 minutes. If the reverse speed is made 16 ips, then the maximum search time would be less than 5.25 minutes of which 5 minutes is the time required to shuttle from one end of the tape to the other.

CONCLUSION

The 19mm helical digital data recording formats allow for multiple search scenarios as long as an understanding of the capabilities and disadvantages of the formats are taken into account. Judicious use of the available features allows for formats which will optimally meet the required search and retrieval requirements.

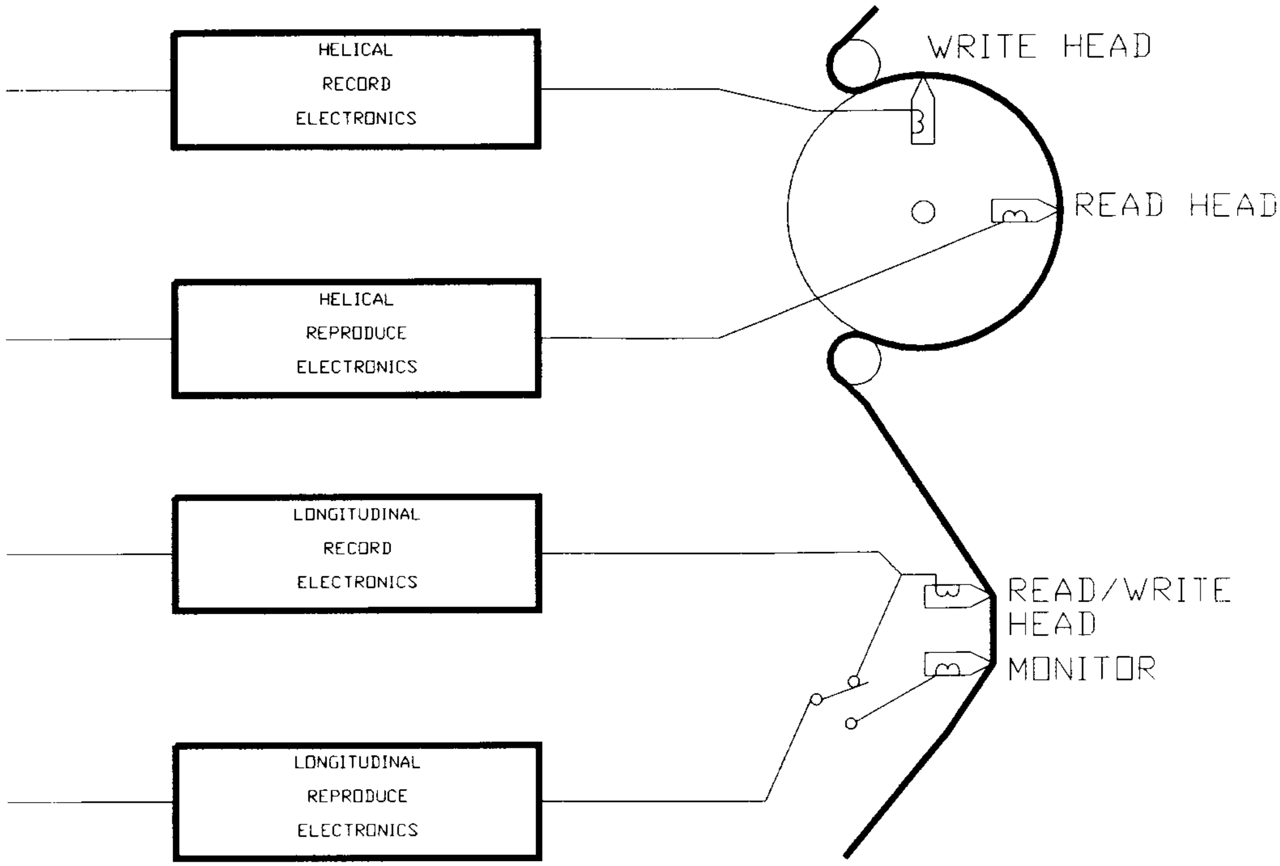

Figure 1. 19mm Recorder Tape Path

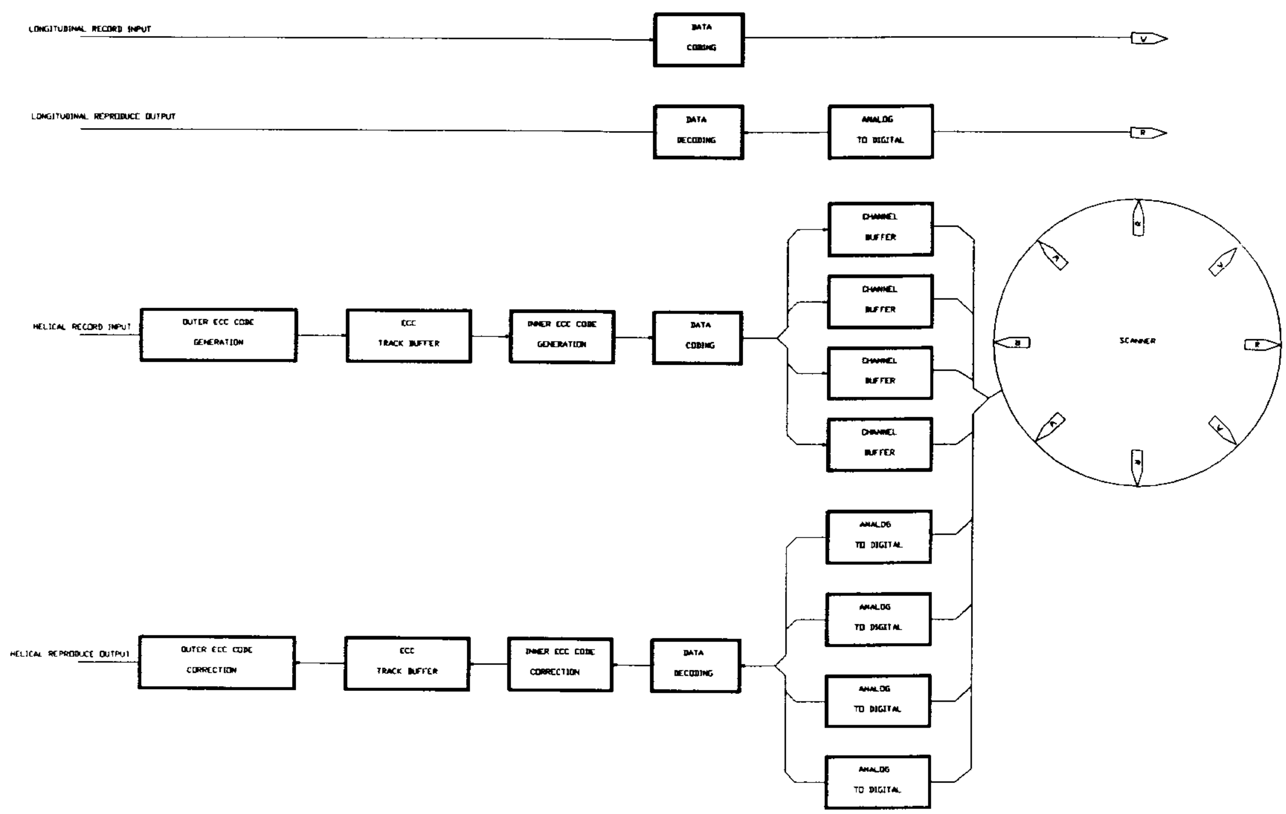

Figure 2. 19mm Recorder Block Diagram